Environmental Control and Sick Building Syndrome; A Comparison between a Low Carbon Open Plan and a Cellular Plan Workplaces

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Individual Thermal Control in the Workplace and Changes in Thermal Preferences in a Day: Norwegian Cellular vs. British Open Plan Layouts

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Abstract

This research suggests that the thermal preference of occupants is subject to change; hence, a particular thermal setting may not be able to constantly satisfy everyone. On the contrary, individual thermal control in the workplace is more likely to increase user comfort and satisfaction. This is examined through environmental measurements, comfort surveys and semi-structured interviews in two office layouts with high and low thermal control. Two Norwegian cellular plan offices that provide each user with control over a window, heating and cooling are compared with two British open plan offices with limited openable windows for users seated around the perimeter of the building. Complementary quantitative and qualitative methodologies and analysis techniques are applied with a particular emphasis on grounded theory and an innovative visual analysing technique. Overall, rather than setting an 'optimum temperature' in an endeavour to satisfy all, it is suggested that buildings provide a degree of flexibility to allow occupants to adjust their thermal environment according to their requirements.

Keywords: Thermal comfort, individual control, workplace, adaptive comfort, steady state theory

1 Introduction

This research is based on the challenge in the field of thermal comfort between the steady state and adaptive comfort theories. These two theories are followed by two separate approaches, the universal comfort zone and adaptive opportunity, respectively. This research challenges the view of the standard comfort zone and investigates the application of adaptive opportunity or thermal control. Therefore two office designs with high and low levels of thermal control are compared. The user satisfaction is compared between Norwegian cellular plan offices with high levels of thermal control and British open plan offices with limited thermal control. In addition, consistency concerning the preference of occupants for a steady thermal condition during the day is examined.

Hawkes states that 'in environmental design, prevention is better than cure' (Hawkes, 2002). Banham recommends including comfort and environmental factors in architecture (Banham, 1984, Bluyssen, 2009). He contends that modern architecture is handed to specialists to provide comfort for occupants and that architects no longer consider environmental criteria in their design. His criticism is that building facades have become more important than the quality of the indoor environment (Banham, 1984). Nicol et al. explain that architects have passed the responsibility for providing thermal comfort in their designed buildings to engineers (Nicol et al., 2012), while the building envelope and the design of thermal control for occupants have a significant influence on the thermal environment as well as user satisfaction.

Users' demands, such as thermal control, have played an important role in the history of the workplace. However, current office designs are moving away from addressing these demands, as organisational goals replace workers' rights (Van Meel et al, 2006) and centrally controlled thermal systems replace user control (Bordass et al., 1993, Roaf et al, 2004). The Workers' Council in Northern Europe is losing its influence (Van Meel et al, 2006) and Scandinavian countries are moving away from the design of the personal offices, which were based on users' demands (Axéll et al, 2005, Gadsjö, 2006). Duffy explains that office design is disconnected from the user, as it has 'little to do with what the man at his desk really needs' (Duffy, 1966). The future of applying users' demands in the workplace is under debate. Harris claims that in the future thermal control will not be necessary as flexibility will replace fixed workstations (Harris, 2006). In contrast, Katsikakis suggests that attracting a talented workforce will be the main concern for organisations, and therefore, providing a pleasant work environment based on users' demands will be essential (Katsikakis, 2006).

2 Steady State vs. Adaptive Comfort Theories

There is a challenge in the field of thermal comfort between the steady state and adaptive comfort theories. The steady state theory emerged after the invention of the refrigerator. Engineers managed to find an 'optimum temperature' to keep meat and food fresh for longer periods. Their success led them to apply the same principle (i.e. optimum temperature) to office buildings, where people work (Nicol et al, 2012). The decision-making and active role of the user as well as the context were overlooked (Nicol et al, 1973). This view considers thermal comfort as a product (Fanger, 1970). It aims to provide a steady thermal condition and present it to the occupants, who passively receive it, in an endeavour to satisfy over 80% of them (ASHRAE Standard 55, 2010). In contrast, the adaptive comfort theory is based on the adaptive nature of the man. The adaptive principle states 'If a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort' (Nicol et al, 1973, Nicol et al, 2012).

The main approach of the steady state researchers is the universal or standard comfort zone. Although adaptive comfort researchers have also contributed to the field for naturally ventilated buildings (ASHRAE, 2004, CEN, 2005, Nicol et al, 2005, Bluyssen, 2009), their main approach is the adaptive opportunity. This is mainly 'an attribute of the building' (Baker et al, 1995) that allows people to 'take advantage of the actual and potential variations in room temperature' (Humphreys, 1996, Baker et al, 1995). The adaptive opportunity is about the building adjusting its thermal environment to meet the needs of occupants (Baker et al, 1995). Melikov explains that 'the heating, ventilation and air conditioning (HVAC) of buildings today is designed to provide a uniform room environment. However, large individual differences exist between occupants in regard to physiological and psychological response … Environmental conditions acceptable for most occupants in rooms may be achieved by providing each occupant with the possibility to generate and control his/her own preferred microenvironment' (Melikov, 2004). Arens reports the relationship between occupants' individual thermal control and 'acceptance of their state' (Arens et al, 2010). Kroner reports high user productivity when individual thermal control is applied (Kroner, 2006).

3 Thermal Control in British Open Plan vs. Norwegian Cellular Plan Offices

The history of the workplace shows users' demands to access thermal control, such as the ability to adjust heating and cooling as well as an openable window. The latter allows an outside view, natural light and ventilation. After World War Two, Scandinavia and Anglo-Saxon countries followed two separate paths in the office design, albeit workers in both places had similar demands (Van Meel, 2000). The 'social democratic office' in Northern Europe and Scandinavia was more concerned with providing a pleasant environment rather than higher salaries and mass production concepts (Myerson, 2008, Forty, 1986). The Workers' Council in Northern Europe played an important role in protecting workers' rights. As a result, Norwegian offices were designed based on users' demands and workers' rights (Van Meel, 2000). Duffy explains that in Northern Europe, 'when users have power the provision of windows and close proximity to windows for everyone becomes tremendously important' (Duffy, 1992). Thus, personal offices with individual control over the thermal environment were provided for each occupant in Norway.

In contrast, the British office design was business oriented and based on efficiency and communication. Although British employees had similar demands to the Scandinavian workers regarding the quality of the indoor environment, they were overruled by the opposition of the British employers. Therefore open plan offices with limited thermal control for occupants were designed (Van Meel, 2000). The managerial and mass production concepts (Hookway, 2009) as well as technological advances, such as telephones and typewriters (Marmot et al, 2000), were the foundation of the open plan office. Lee and Brand explain that the Anglo-Saxon open plan layout was introduced as a flexible solution to many of the historic and contemporary challenges (Lee et al, 2005). Laing describes the British office as 'a self-regulating structural grid within which working groups grow and change' (Laing, 2006). The invention of air conditioning (i.e. 1930s) and florescent lights (i.e. 1940s) allowed the possibility of deep open plan offices with no need for natural light and ventilation (Laing, 2006). Duffy explains that in an open plan office, 'desks and equipment are arranged in ordered rows. Such offices are often very large, as staff work far from the windows, artificial light and ventilation are required' (Duffy, 1966). He indicates that users did not find this kind of office popular due to the unfriendly classroom set up, distractions and lack of individual environmental control (Duffy, 1992).

The Anglo-Saxon open plan offices are based on standardising the layout (Laing, 2006) as well as providing a uniform and standard thermal environment (Nicol et al, 2012). The main thermal system is centrally controlled to ensure the indoor air quality. For instance, in a naturally ventilated office, occupants may not open the windows in the winter, which increases the carbon dioxide level. Therefore, a centrally controlled system is required. In this system, thermal control is provided as a secondary option so that if occupants are uncomfortable they have the ability to adjust the thermal environment (Bordass et al, 1993). Hawkes explains that the manual control is only for 'fine-tuning' in case of a system failure (Hawkes, 2002). In contrast, in Scandinavia individual thermal control is the main source of adjusting the thermal environment. In order to ensure the temperature and indoor air quality are within the acceptable range, centrally controlled mechanical ventilation with adequate air exchange operates in the background (Arbeidstilsynet, 2003).

4 Methodologies

Although the traditional approach in thermal comfort is through quantitative methodologies, recently the application of qualitative methodologies is encouraged (Hitchings, 2009). In this research, a combination of quantitative and qualitative methodologies is applied with a particular emphasis on grounded theory. The latter is a cyclic process of research planning, collecting and analysing data (Glaser et al, 1967). Several pilot studies were examined to refine the research plan. Measurements of the thermal environment were applied to record the building performance together with simultaneous survey questionnaires to record the view of occupants concerning the thermal environment. Each workstation was investigated three times a day: morning, early and late afternoon. The ASHRAE seven-point scale thermal sensation (e.g. slightly cool, neutral and slightly warm), comfort and satisfaction as well as thermal intention (e.g. slightly cooler, no change and slightly warmer) comprised the main factors. These traditional methods were reinforced with semi-structured interviews to further investigate the application of thermal control. Overall, four case study buildings were investigated and 103 respondents participated in this research, which included approximately thirty respondents in each of the four buildings. Each participant responded to the survey questionnaire three times a day. Quantitative and qualitative analysis techniques were applied on the collected data. An innovative visual recording technique was introduced to analyse the information according to the context and meaning.

5 Building Performance

In this research, two British open plan offices with limited thermal control are compared with two Norwegian cellular plan offices with high levels of thermal control. The building performance of all four case study buildings are analysed regarding the ventilation system, carbon dioxide level, energy and thermal performance.

5.1 Ventilation System

In the cellular plan offices, air conditioning is working in the background. However, the main system provides each occupant with access to an openable window, blinds, door and the ability to adjust the cooling or heating. In contrast, in the open plan offices, the centrally controlled mechanical system is the main ventilation system, while limited occupants seated around the perimeter of the building can access openable windows and blinds, as presented in Figure 1 and Figure 2. In the Norwegian offices, each occupant is expected to adjust the heating through the available individual control systems to find their own comfort. In contrast, in the British offices, the centrally controlled thermal system presents comfort to the occupants and limited openable windows are provided in case occupants are uncomfortable.

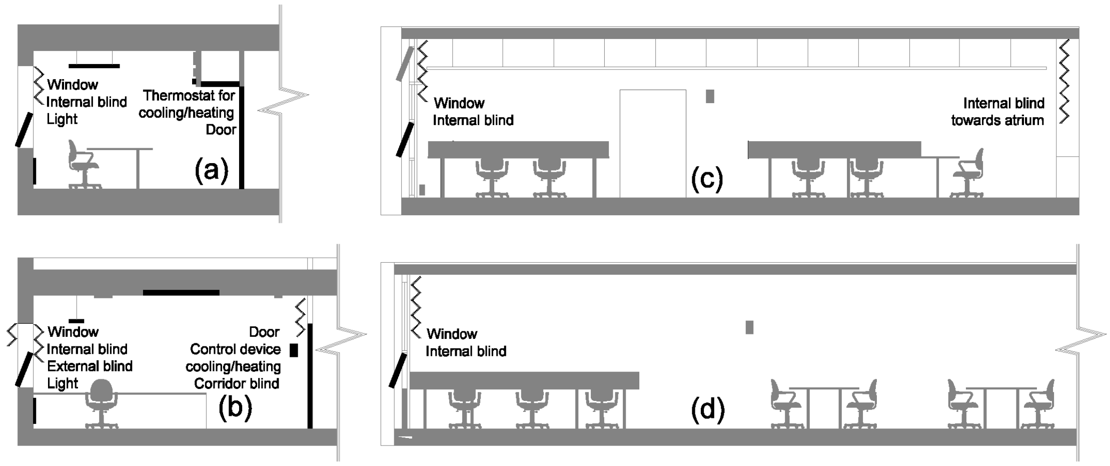

Figure 1: Sections, individual environmental control in (a) and (b): Norwegian cellular plan offices and (c) and (d): British open plan offices

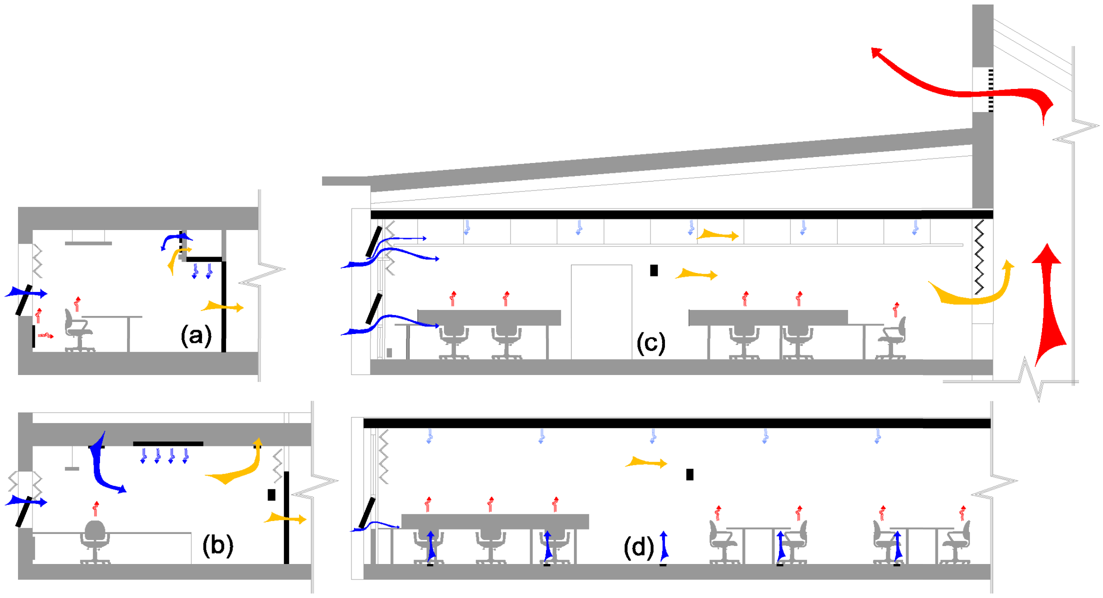

Figure 2: Sections, summer day ventilation in in (a) and (b): Norwegian cellular plan offices and (c) and (d): British open plan offices

5.2 Carbon Dioxide Level

The comparison of the carbon dioxide level between the case study buildings shows that the air quality of all four buildings falls into the acceptable range, as presented in Figure 3.

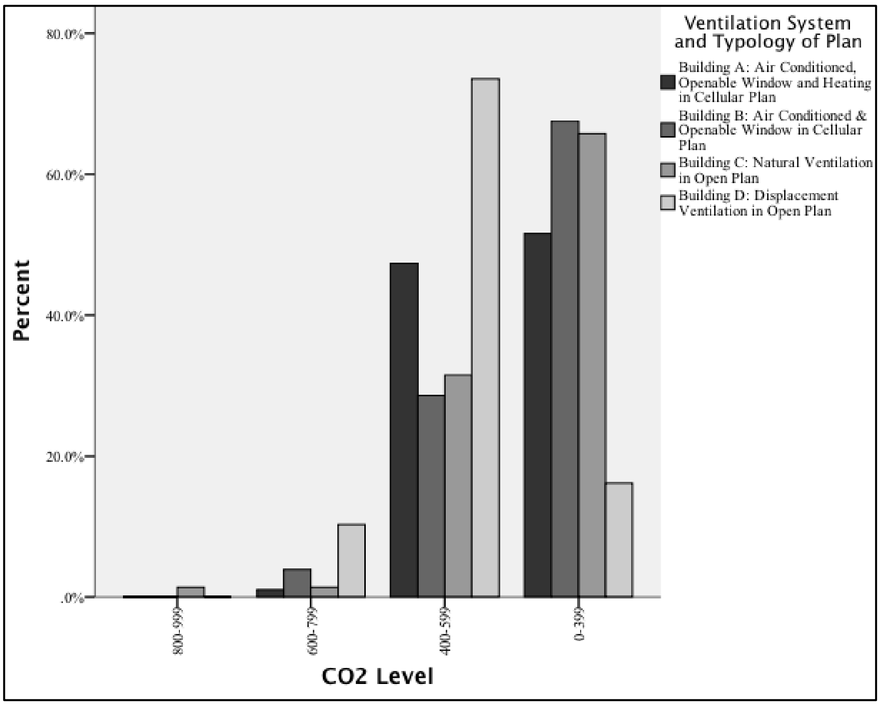

Figure 3: SPSS frequency bar chart, comparing the CO_2 levels between the four case study buildings

5.3 Energy Consumption

The energy consumption analysis shows that except for one of the Norwegian cellular plan offices, all the other buildings are within the acceptable range of the CIBSE benchmark (CIBSE, 2003), as presented in Figure 4.

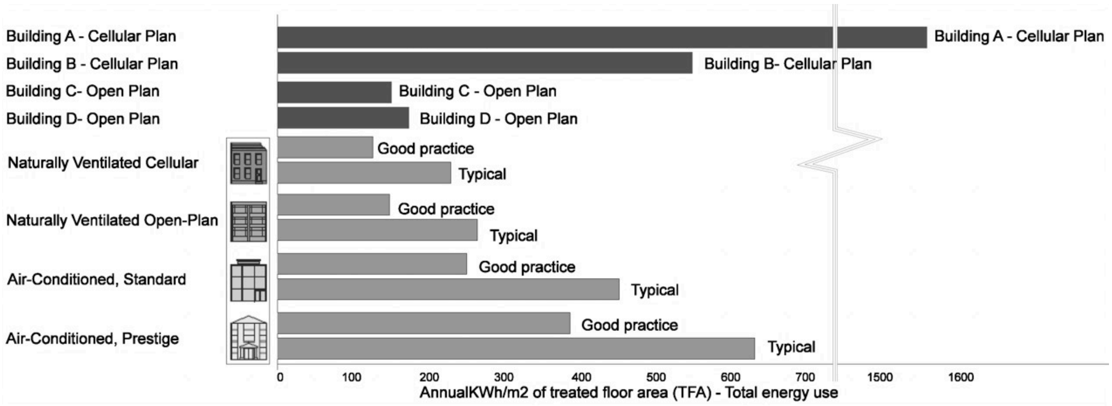

Figure 4: Energy consumption of the four case study buildings KWh/m^2 per year

5.4 Thermal Comfort Predictions

The thermal measurements of every workstation are analysed using the ASHRAE Thermal Comfort Tool (Huizenga, 2011), which is based on the ASHRAE Standard 55-2010. The adaptive comfort prediction model shows that all four buildings are expected to have comfortable thermal environments, as presented in Figure 5.

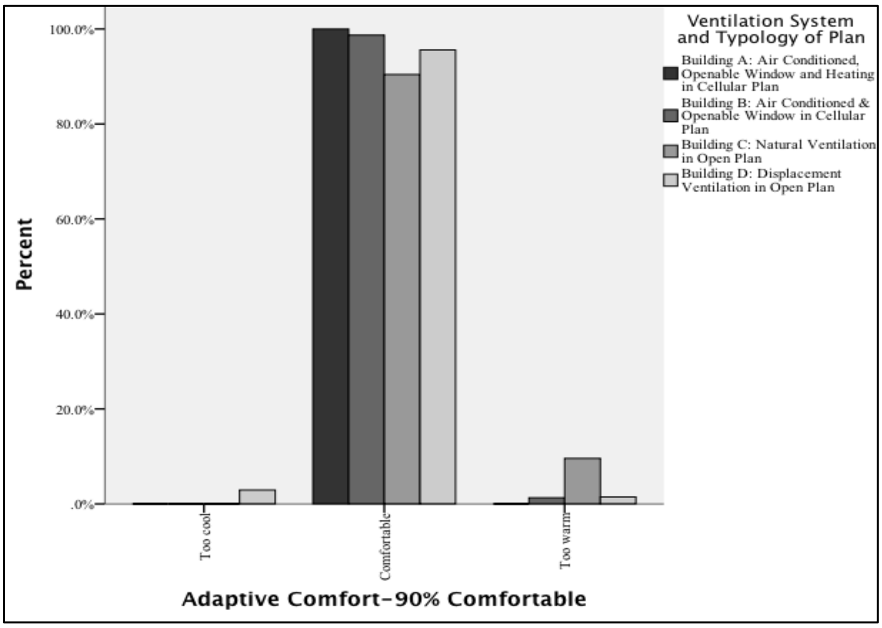

Figure 5: SPSS bar chart, frequency analysis of the ASHRAE adaptive model in the four buildings

Overall, the building performance analysis indicates that all four case study buildings provide high standards of indoor thermal environment. They are within the benchmark and expected to provide comfortable thermal environments. Therefore the difference in the comfort and satisfaction levels of the users is less likely to be related to the quality of the thermal environment, which is confirmed by the follow up interviews.

6 Steady vs. Dynamic Thermal Preference

The consistency of overall thermal preference of each occupant throughout the day is examined in this section. An innovative visual recording technique is introduced to analyse the data qualitatively according to the context and meaning.

6.1 Visual Recording Technique

Thermal comfort is often researched by engineers (Meir et al, 2009), who apply mainly quantitative analysis methods. Nicol et al explain that ‘Architects have gradually passed responsibility for building performance to service engineers, who are largely trained to see comfort as a “product”, designed using simplistic comfort models’ (Nicol et al, 2012). The research outcomes of engineers are based on ‘mathematical language and logic’ (Gaucherel et al, 2011), which may not appear so convenient to architects. In order to encourage architects to contribute to the field of thermal comfort, the use of a familiar language is useful. ‘Visual tools are commonly used in the field of architecture to apply information on plans and sections. They add a different value and perspective by putting together different information regarding a specific aspect in a visual way’ (Shahzad, 2013). In addition, the traditional quantitative analysis of thermal comfort is useful to examine the physical reactions, to refine the standard comfort zone and to compare a variable between two buildings. However, it overlooks the context and meaning, which are highlighted in this research. Shahzad explains that ‘the interpretation of the connection between information through a quantitative approach could drive to a misjudgement’ (Shahzad, 2013).

In this research, careful consideration is given to keep the connection between the collected data and the context. Therefore, a qualitative analysis technique is introduced to analyse the data by means of contextual information, including time, thermal sensation and intention, as presented in Figure 6. This pictogram is a top view of a seated person. The colours inside the ellipses symbolising the person's body, indicate the person's reported survey at the time of the measurements at their particular workstation. The colour of the person's head shows their thermal intention, which is their desire to change the temperature. The space between the arms indicates the thermal sensation of the person. The overall thermal preference of an individual is a combination of the thermal sensation and thermal intention of that person. Green shows a neutral thermal sensation or no change in the temperature, while red and blue indicate warm and cold sensations, respectively. Figure 7 shows a sample of the information on the plans of the two buildings.

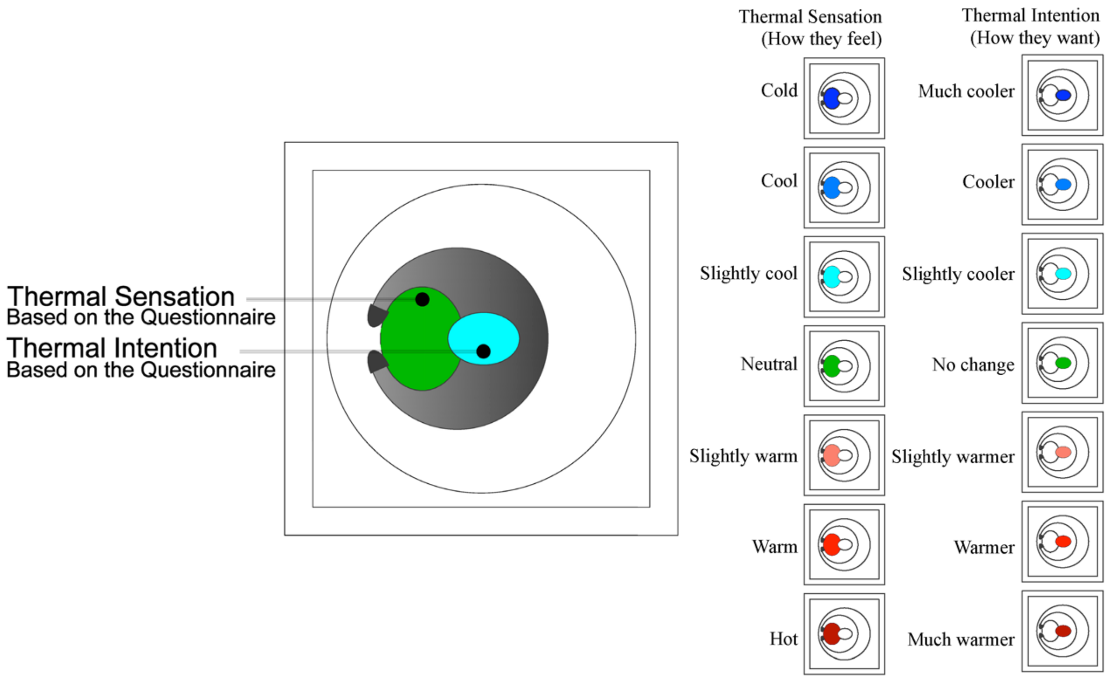

Figure 6: Visual recording technique: Thermal sensation and thermal intention of a respondent

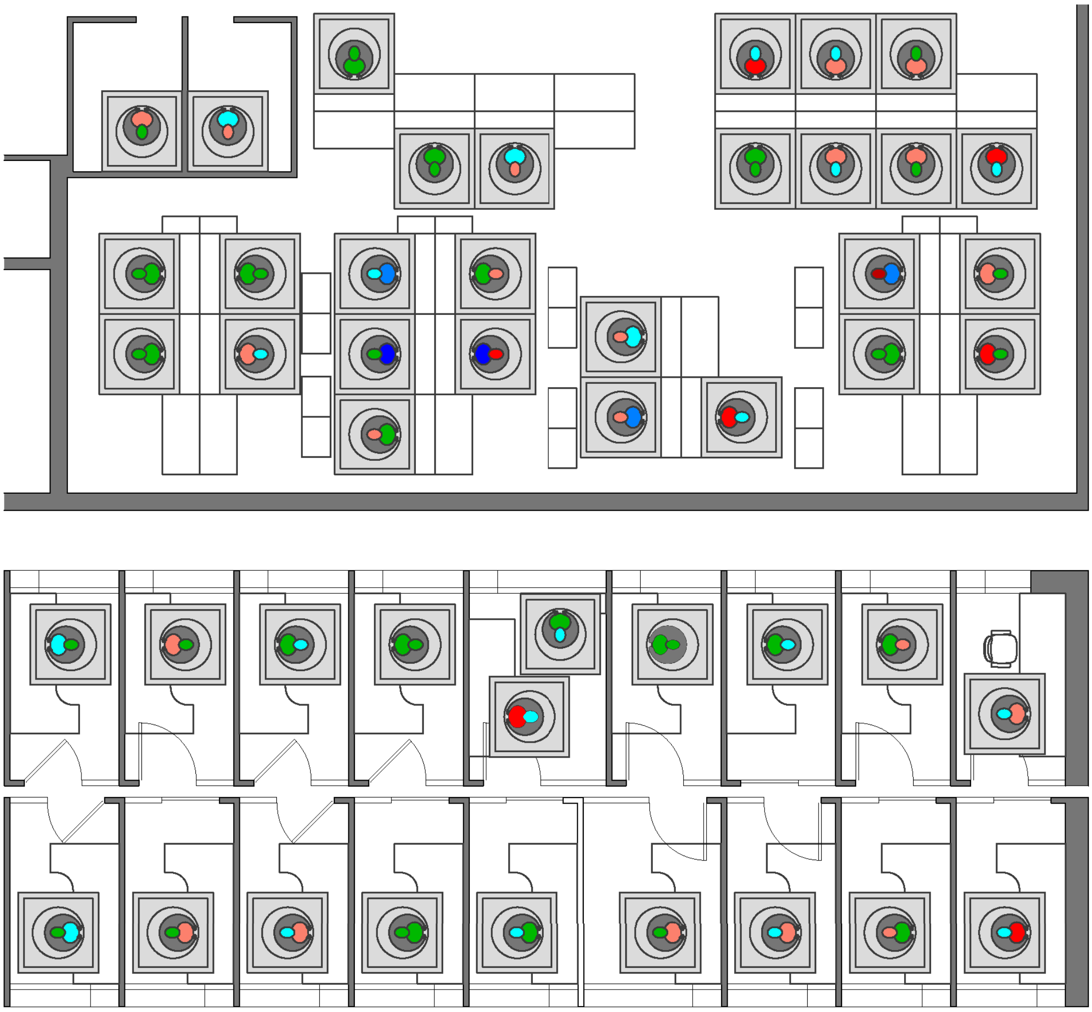

Figure 7: A sample of the visual recording technique, morning recordings of buildings B and D

6.2 Consistency of Thermal Preference

Figure 12 examines the consistency of the thermal preference of the occupants throughout the day. The morning, early and late afternoon recordings for each individual are extracted from the plan and compared. Figure 8 shows how to read the information in Figure 12. Although the presented individual in Figure 8 feels neutral during the day, their thermal intention changes from ‘slightly warmer’ in the morning and early afternoon to ‘no change’ in the late afternoon. In this case, the overall thermal preference of the person changes from ‘slightly warm’ in the morning and early afternoon to ‘neutral’ in the late afternoon. Therefore, the thermal preference of this occupant is ‘not consistent’, which is demonstrated by a red cross in the pictogram. This indicates that the person is comfortable feeling ‘slightly warm’ at the beginning and midday, while ‘neutral’ closer to the end of the working day, rather than a consistent thermal preference throughout the day. In order to read the information in Figure 12, three more samples are presented. The samples in Figure 9 and Figure 10 show consistency in the thermal preference, while Figure 11 demonstrates inconsistency in the thermal preference of an individual during the day.

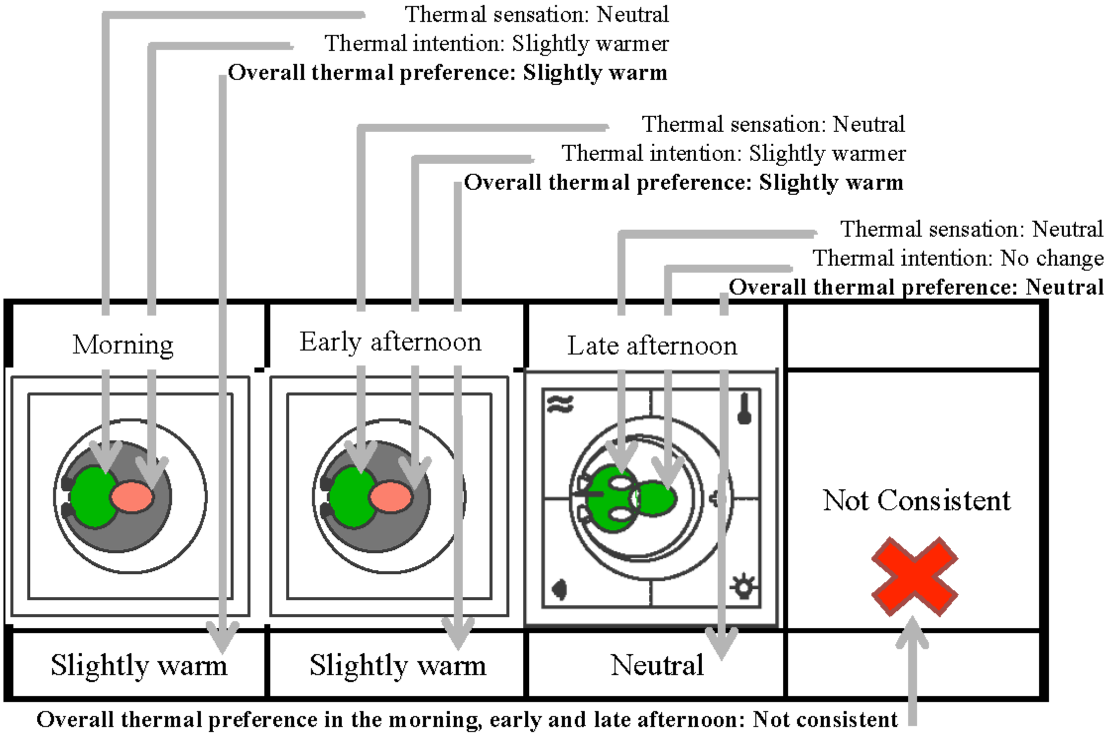

Figure 8: Overall thermal preference is inconsistent and it changes from 'slightly warm' in the morning and early afternoon to 'neutral' in the late afternoon (all based on survey questionnaires)

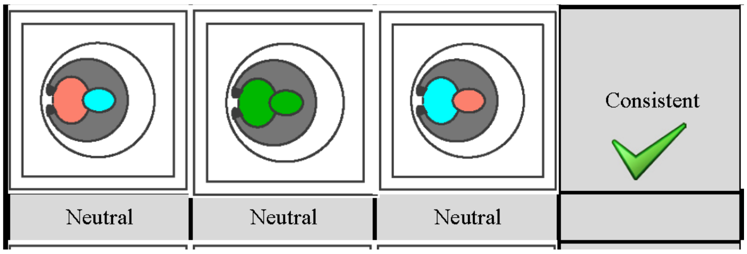

Figure 9: Overall thermal preference is consistently 'neutral' in the morning, early and late afternoon

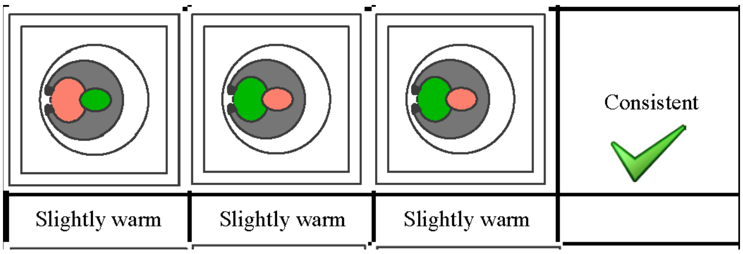

Figure 10: Overall thermal preference is consistently 'slightly warm' during the day

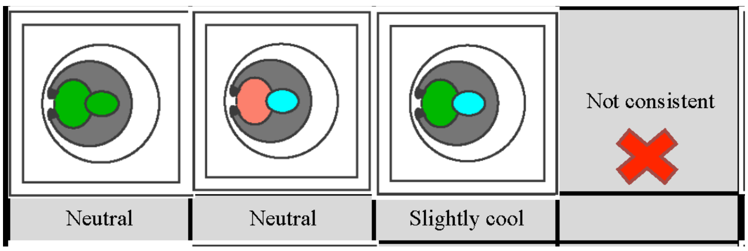

Figure 11: Overall thermal preference is inconsistent, changing from 'neutral' in the morning and early afternoon to ' slightly cool' in the late afternoon

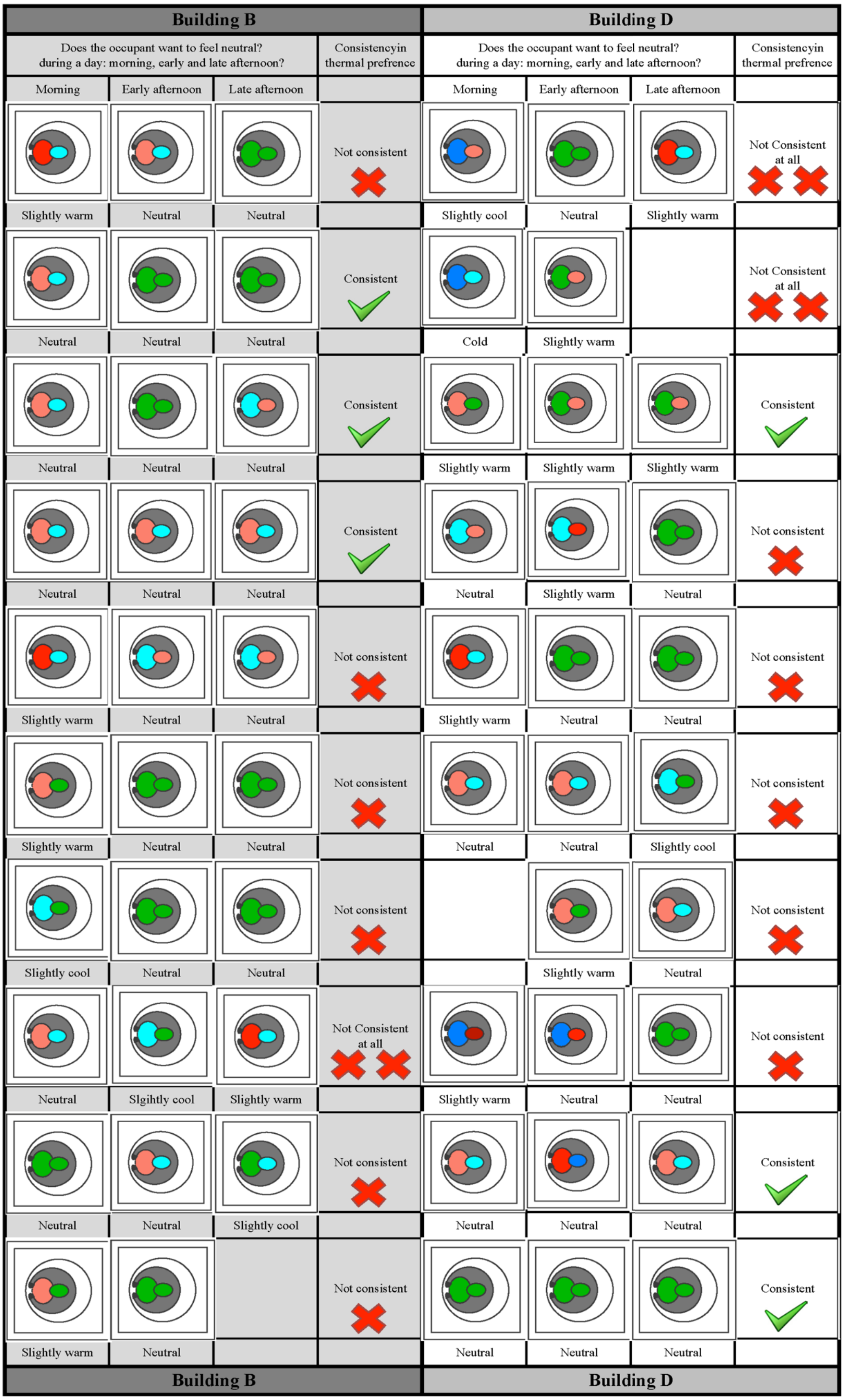

Figure 12: A sample of the visual recording analysis of consistency in overall thermal preference of each participant in the morning, early and late afternoon

Consistency of Thermal Preference of Occupants During the day		Building A	Building B	Building C	Building D	All 4 Buildings
Consistant	✓	21	6	10	9	46
Not consistant	✗	9	16	10	9	44
Not consistant at all	✗✗	0	4	4	5	13

Figure 13: Consistency of thermal preference of occupants throughout the day

Figure 13 shows the number of individuals with consistent and inconsistent thermal preference in the four case study buildings. 46 out of 103 participants in the four case study buildings (i.e. 45%) have consistency in their thermal preferences in the morning, early and late afternoon. However, in 57 cases (i.e. 42%) there is limited inconsistency in the thermal preferences of individuals during the day. 13 individuals (i.e. 13%) have extreme preferences during the day. Overall, more than half of the participants in this study (i.e. 55%) have different thermal preferences during the day and their desired set point of temperature changes.

7 Individual Thermal Control

In this section, the two British open plan offices are compared to the two Norwegian cellular plan offices regarding occupants' satisfaction and comfort. Quantitative analysis methods are applied.

7.1 Quantitative Analysis

Quantitative analysis using the SPSS linear regression analysis is applied to compare the satisfaction and comfort in the four case study buildings. The P value of both variables (i.e. 0.000) is less than 0.05, which suggests a significant relationship between each variable (i.e. satisfaction and comfort) and type of plan (i.e. open and cellular plan offices). The SPSS frequency analysis shows that the satisfaction levels of satisfied and very satisfied respondents in the two open plan offices are close (i.e. 30%), and that the satisfaction levels in the two cellular plan offices are also close (i.e. 60%). It also indicates that the comfort levels of comfortable and very comfortable respondents in the two open plan offices are close (i.e. above 55%), and the satisfaction levels in the two cellular plan offices are also close (i.e. above 75%). The analysis of satisfaction and comfort are presented in Figure 14 and Figure 15, respectively. The darker lines represent the two Norwegian cellular plan offices, while the lighter lines indicate the two British open plan offices.

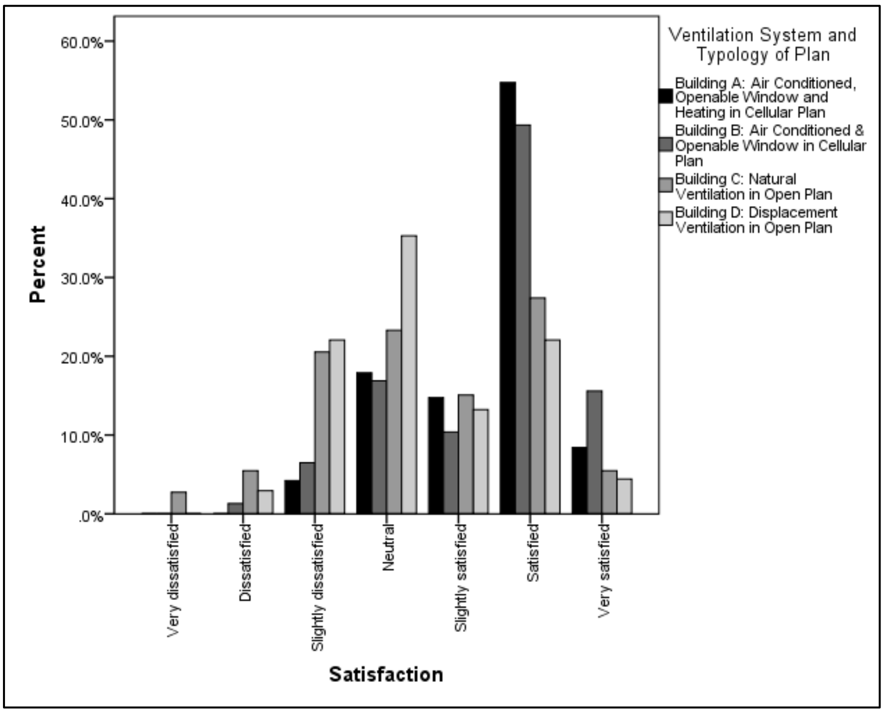

Figure 14: Satisfaction level in the four case study buildings

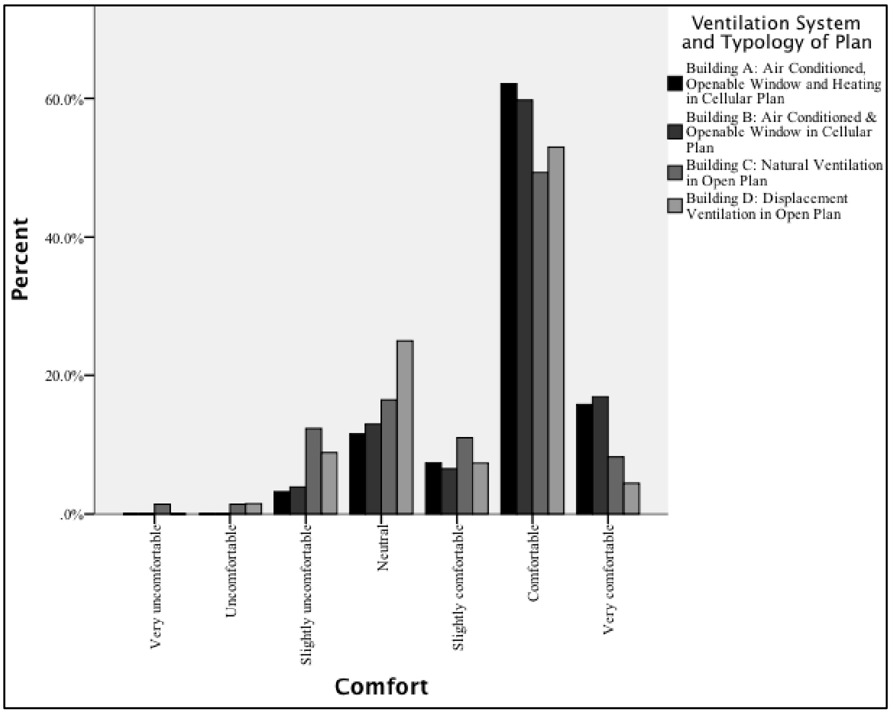

Figure 15: Comfort level in the four case study buildings

Overall the results suggest that, respectively, satisfaction and comfort are 30% and 20% higher in the cellular plan compared to the open plan offices.

8 Discussion

The results of this research demonstrate the inconsistency in the thermal preference of individuals throughout the day. The results suggest that the thermal preference of a particular individual is subject to change. Over half of the respondents did not have a steady thermal preference during the day, preferring different thermal settings at different times. This suggests that an individual is more likely to expect different thermal conditions at different times in order to feel comfortable. Therefore a particular thermal setting, such as in a centrally controlled thermal system, is less likely to satisfy a particular individual at all times. Hence, when a particular thermal setting from the standard comfort zone is applied to the office constantly, there is no guarantee that every individual occupant is constantly comfortable. This poses a difficulty to the steady state theory and the concept of comfort zone, as it suggests that the thermal preference of each individual is dynamic rather than fixed. This finding is in contrast to the view of the steady state thermal setting that constantly satisfies over 80% of the occupants. It suggests that no matter how much the standard comfort zone is refined, it is less likely to be applied to real world situations because thermal comfort is dynamic and a fixed temperature is less likely to provide thermal comfort.

The other finding in this research suggests that the occupants of the two Norwegian cellular plan offices with higher levels of individual thermal control are more satisfied and comfortable compared to those in the two British open plan offices with limited thermal control. This is in line with workers' demands in the 1970s regarding openable windows and individual thermal control (Van Meel, 2000). The satisfaction and comfort levels of the Norwegian offices are respectively 30% and 20% higher than the British offices. The building performance and thermal environment of the four buildings was within the acceptable range and the major difference between these two offices is the availability of thermal control for the users. This suggests that the availability of thermal control increases user satisfaction and comfort. In addition, the interview results confirm this finding, as the Norwegian respondents explained the significant influence of individual thermal control in their personal offices on their satisfaction and comfort. In contrast, the British respondents complained about the lack of thermal control and its undesirable influence on their satisfaction and comfort. The majority of them had to tolerate the situation when they found the thermal environment uncomfortable. Sometimes they found it so difficult to cope with the thermal condition at their workstation that they put on inconvenient clothing layers, such as a sleeping bag, or they stayed at home. In addition, this finding is in line with other research in the field, which indicates that thermal control increases satisfaction (Wagner et al, 2007, Brager et al, 2009, Newsham et al, 2009) and comfort (Bordass et al, 1993).

Although Nicol and Humphreys do not agree with all aspects of the thermal standards, they explain that 'thermal comfort standards are required to help building designers to provide an indoor climate that building occupants will find thermally comfortable' (Humphreys et al, 2002). The further the indoor thermal conditions are from the standard comfort zone, the more likely it is that occupants will be uncomfortable (Nicol et al, 2005). Although the knowledge of the standard comfort zone is useful at the design level, this research suggests that a thermal condition that is set based on the standards does not guarantee thermal comfort. Nicol and Humphreys suggest that workplace design should focus on thermal control systems and their operation rather than on providing an optimum thermal environment (Nicol et al, 1973).

9 Conclusion

This research suggests that rather than providing a uniform thermal condition according to the standard 'comfort zone', office buildings are recommended to provide a degree of flexibility to allow users to find their own comfort by adjusting their thermal environment according to their immediate requirements. It is also proposed that thermal comfort is dynamic, as the thermal preference of the occupants changes at different times.

The Scandinavian cellular plan offices presented in this research are good practice examples of providing individual thermal control for each occupant through the architectural design and office layout. The architectural design of the personal office provides each occupant with an openable window for an outside view, natural light and ventilation, in addition to blinds, a door and a thermostat to adjust the temperature. The Scandinavian cellular office layout respects individual differences and allows all users to adjust the thermal environment based on their individual requirements without interfering with other occupants' thermal settings. In the Norwegian case study buildings, occupants find their own comfort by adjusting the thermal environment, while in the British case studies comfort is offered through a centrally controlled thermal system with additional adaptive opportunity for fine-tuning. The individual thermal control is the key factor in higher user satisfaction and comfort in the Norwegian cellular plan offices compared to the British open plan offices in this research.

Two main difficulties limit this research and its findings: an obstacle regarding this particular research and a complexity that is associated with the field studies of thermal comfort. Respectively, accessing the buildings and the complexities of the context are the main constraints in this research, which lead to a difficulty in generalising the findings.

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References

ARBEIDSTILSYNET 2003. *Control and Guidance on Working: Veiledning om klima og luftkvalitet på arbeidsplassen - fulltekst*. In: ARBEIDSTILSYNET (ed.). Norway.

ARENS, E., HUMPHREYS, M. A., DE DEAR, R. & ZHANG, H. 2010. *Are 'Class A' Temperatue Requirements Realistic or Desirable?* Building and Environment, 45**,** 4-10.

ASHRAE 2004. *ASHRAE Standard 55-2004*. USA: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE 2010. *ASHRAE Standard 55*. In: COOPER & W., K. (eds.) *Thermal Environmental Conditions for Human Occupancy.* Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

AXÉLL, C. & WARNANDER, A. 2005. *How to Create Optimal Office Solutions.* MSc, KTH University.

BAKER, N. & STANDEVEN, M. 1995. *A Behavioural Approach to Thermal Comfort* Assessment. International Journal of Solar Energy, 19**,** 21-35.

BANHAM, R. 1984. *The Architecture of Well-Tempered Evironment,* Chicago and London, The University of Chicago Press and The Architectural Press Ltd.

BLUYSSEN, P. M. 2009. *The indoor environment handbook : how to make buildings healthy and comfortable,* London, Earthscan.

BORDASS, B., BROMLEY, K. & LEAMAN, A. 1993. *User and Occupant Controls in Office Buildings.* Building Use Studies.
BRAGER, G. S. & BAKER, L. 2009. *Occupant Satisfaction in Mixed-Mode Buildings.* Building Research and Information, 37, 369-380.
CEN 2005. *European Standard, CEN prEN 15251. Criteria for the Indoor Environment Including Thermal,* Indoor Air Quality, Light and Noise. Brussels: CEN.
CIBSE 2003. *Energy Consumption Guide 19: Energy Use in Offices. Best Practice Programme.* The Chartered Institution of Building Services Engineers.
DUFFY, F. 1966. The Case for Bürolandschaft. In: DUFFY, F. (ed.) *The Canging Workplace.* London: Phaidon Press Limited.
DUFFY, F. 1992. *The Changing Workplace,* London, Phaidon Press Limited.
FANGER, P. O. 1970. *Thermal Comfort; Analysis and Applications in Environmental Engineering,* New York, McGraw-Hill Book Company.
FORTY, A. 1986. *Objects of Desire: Design and Society: 1750*, Thames & Hudson.
GADSJÖ, A. 2006. *Hur påverkas hyresgästanpassningar framtida hyresintäkter? (How Does Improvement in Tenant Influence The Future of Rental Income?).* KTH.
GAUCHEREL, C., BERARD, S. & MUNOZ, F. 2011. *Equation or Algorithm: Differences and Choosing Between Them.* Acta Biotheor, 59, 67-79.
GLASER, B. G. & STRAUSS, A. L. 1967. *The discovery of grounded theory : strategies for qualitative research,* Chicago: Aldine Pub. Co.
HARRIS, R. 2006. *Real Estate and the Future.* In: WORTHINGTON, J. (ed.) *Reinventing the Workplace.* London: Architectural Press, Elsevier.
HAWKES, D. 2002. *The Selective Environment; An approach to environmentally responsive architecture,* London, Spon Press.
HITCHINGS, R. 2009. *Studying Thermal Comfort in Context.* Building Research and Information, 37, 89-94.
HOOKWAY, B. 2009. *Rules of Engagement: Arhchitecture Theory and the Social Sciences in Frank Duffy's 1974 Thesis on Office Planning*, Princeton University.
HUIZENGA, C. 2011. *ASHRAE Thermal Comfort Tool CD, Version 2: Maintains Consistency with ANSI/ASHRAE Standard 55-2010*. ASHRAE.
HUMPHREYS, M. A. 1996. *Thermal Comfort Temperatures World-Wide: The Current Position.* WREC 1996.
HUMPHREYS, M. A. & NICOL, J. F. 2002. *Adaptive Themal Comfort and Sustainable Thermal Standards for Buildings.* Energy and Buildings, 34, 563-572.
KATSIKAKIS, D. 2006. *New Real Estate Models to Support Distributed Working*. In: WORTHINGTON, J. (ed.) *Reinventing the Workplace.* London: Architectural Press, Elsevier.
KRONER, W. M. 2006. *Employee Productivity and the Intelligent Workplace.* In: CLEMENTS-CROOME, D. (ed.) *Creating the Productive Workplace.* London: Taylor & Francis.
LAING, A. 2006. *New Patterns of Work: The Design of the Office.* In: WORTHINGTON, J. (ed.) *Reinventing the Workplace.* London: Architectural Press, DEGW.
LEE, S. Y. & BRAND, J. L. 2005. *Effencts of control over office workspace on perceptions of the work environment and work outcomes.* Elsevier.

MARMOT, A. & ELEY, J. 2000. *Office Space Planning; Design for Tomorrow's Workplace,* New York, London, Sydney, McGraw-Hill.

MEIR, I. A., CARB, Y., JIAO, D. & CICELSKY, A. 2009. *Post Occupancy Evaluation: An Inevitable Step Toward Sustainability.* Advances in Building Energy Research, Earthscans Journals. Santamouris: aber.

MELIKOV, A. 2004. *Personilised Ventilation.* Indoor Air, 14**,** 157-167.

MYERSON, J. *Power of the Network: Transitions in Working Life from Taylorist Time and Motion to Networked Space.* In: GLYNNE, J. & IACKNEY, F., eds. *Networks of Design*: Proceedings of the 2008 Annual International Conference of the Design History Society (UK), 2008 University College Falmouth. Universal Publishers.

NEWSHAM, G., BRAND, J., DONNELLY, C., VEITCH, J., ARIES, M. & CHARLES, K. 2009. *Linking Indoor Environment Conditions to Job Satisfaction: A Field Study.* Building Research and Information, 39**,** 129-147.

NICOL, F. & HUMPHREYS, M. A. 2005. *Maximum Temperature in Buildings to Avoid Heat Discomfort.* International Conference 'Passive and Low Energy Cooling for the Built Environment'. Santorini, Greece.

NICOL, F., HUMPHREYS, M. A. & ROAF, S. 2012. *Adaptive Thermal Comfort: Principles and Practice*, Routledge.

NICOL, J. F. & HUMPHREYS, M. A. 1973. *Thermal comfort as part of a self-regulating system.* Builiding Research & Information, 1**,** 174-179.

ROAF, S., HORSLEY, A. & GUPA, R. 2004. *Closing the loop; Benchmarks for sustainable buildings,* London, RIBA Enterprises Ltd.

SHAHZAD, S. S. 2013. *Quantitative vs. Qualitative Methodologies to Invesitage Environmental Control in the Workplace: Neutral Thermal Sensation and Thermal Environmental Intention*. PLEA: Sustainable Architecture for a Renewable Future. Munich: PLEA.

VAN MEEL, J. 2000. *The European Office: Office Design and National Context,* Rotterdam, 010 Publishers.

VAN MEEL, J. & DE JONGE, H. 2006. *Office Cultures: International Differences in Workplace Design*. In: WORTHINGTON, J. (ed.) *Reinventing the Workplace.* London: Architectural Press, Elsevier.

WAGNER, A., GOSSAUER, E., MOOSMANN, C., GROPP, T. & LEONHART, R. 2007. *Thermal comfort and workplace occupant satisfaction: Results of field studies in German low energy office buildings.* Energy and Building, 39**,** 758-769.